Online Management of Virtual Networks

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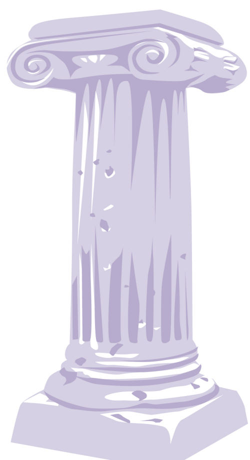
Virtu Research Areas: The 3 Pillars

Service migration

VNet embeddings



Economics

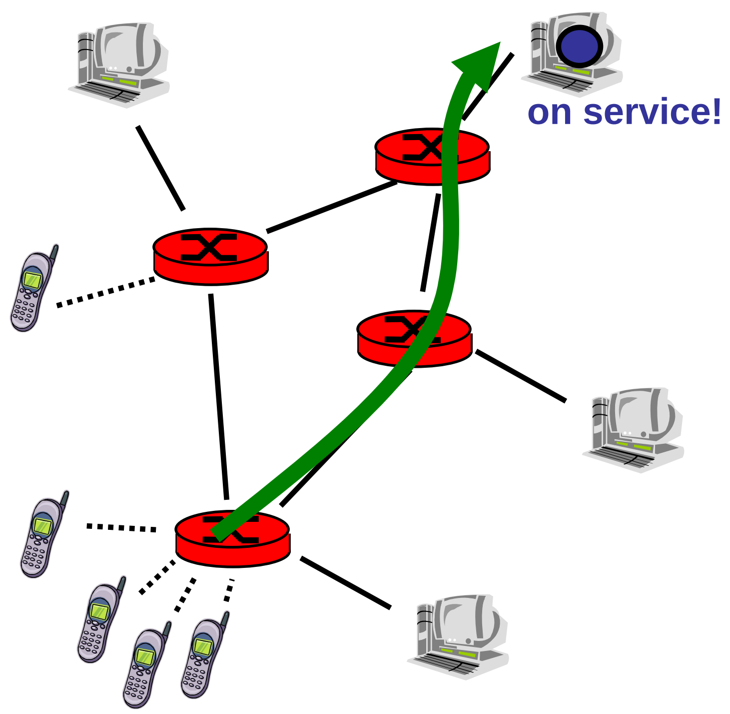
Virtu + Online Algorithms = ♥

Network Virtualization: High-level Concepts

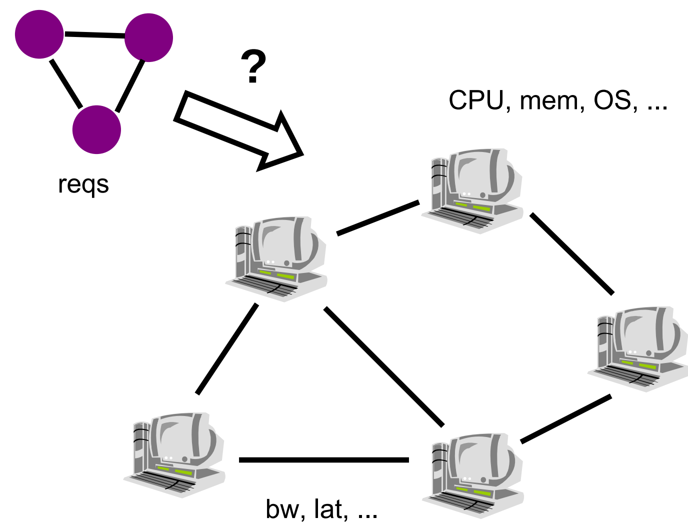
Decoupling services from physical infrastructure

- dynamic virtual network embeddings, sharing of resources, „smarter core“

Example 1: A mobile service provider can move services to locations where they are most useful: migration vs QoS tradeoff



Example 2: Virtual networks (VNets) can be allocated where the least resources are used, or where most energy can be saved, or...:



Virtualization Business Roles

Envisioned business roles:

PIP

Physical infrastructure provider (PIP):

owns and manages physical infrastructure („substrate“), supports network virtualization (e.g., GENI: no federation, one PIP only)

VNP

Virtual network provider (VNP):

assembles virtual resources from PIPs into virtual topology, makes negotiations, etc. (e.g., GENI clearinghouse)

VNO

Virtual network operator (VNO):

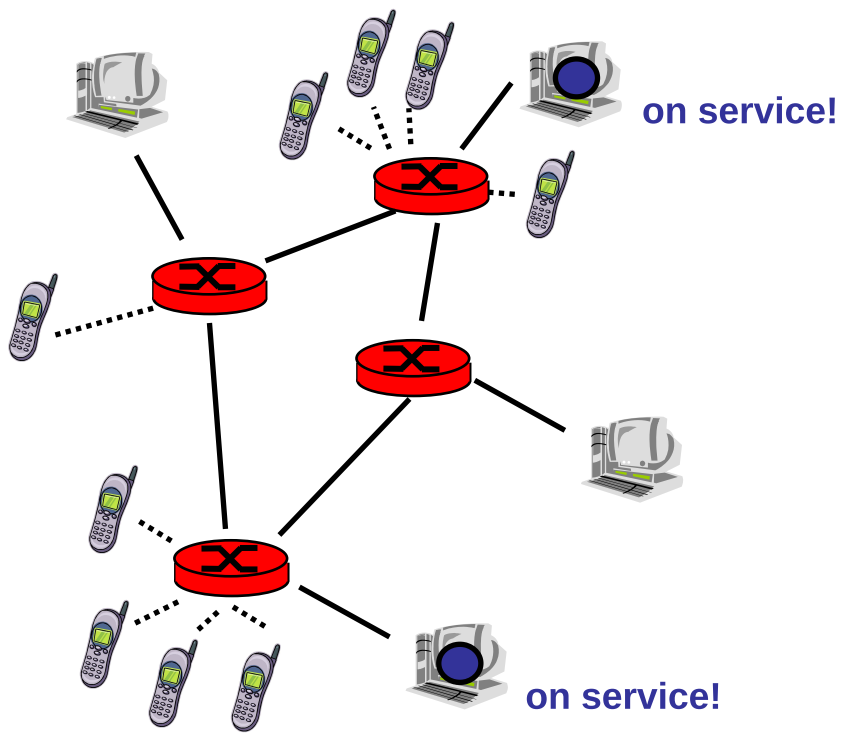
installation and operation of VNet according to SP needs, e.g., triggering cross-PIP migration, etc.

SP

Service provider (SP):

uses VNet to offer services (application or transport service)

Online Service Migration



Access pattern changes, e.g., due to mobility (commuter scenario), due to time-of-day effects (time-zone scenario), etc.

... when and where to move the service??

Virtu + Online Algorithms = ♥

How to deal with dynamic changes (e.g., mobility of users, arrival of VNets, etc.)?

Online Algorithm

Online algorithms make decisions at time t without any knowledge of inputs / requests at times t'>t.

Competitive Ratio

Competitive ratio r,

r = Cost(ALG) / cost(OPT)

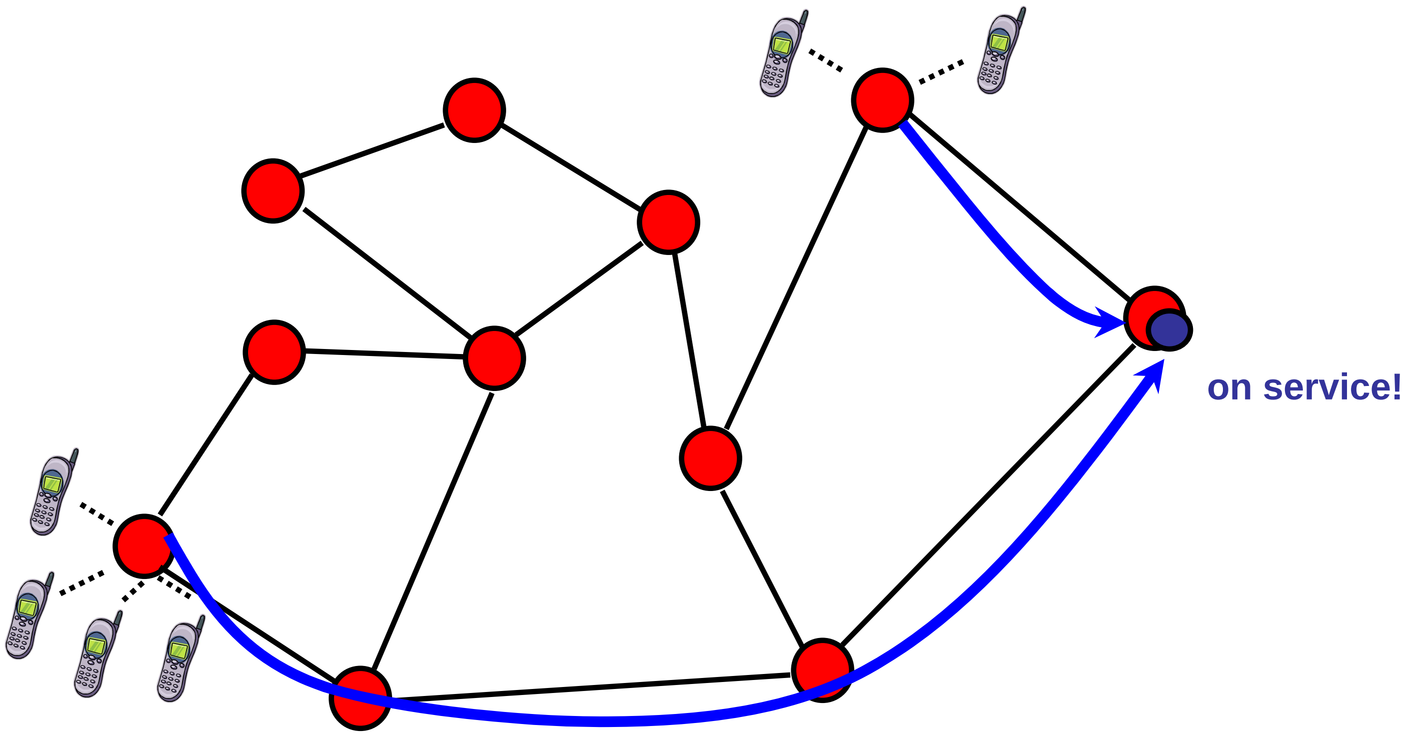
Is the price of not knowing the future!

Competitive Analysis

An *r-competitive online algorithm* ALG gives a worst-case performance guarantee: the performance is at most a factor r worse than an optimal offline algorithm OPT!

In virtual networks, many decisions need to be made online: online algorithms and network virtualization are a perfect match! ☺

Online Service Migration 1 PIP, 1 Server: Easy



Assume: one service, migration cost *m* (e.g., service interruption cost), access cost 1 per hop (or sum of link delays).

When and where to move for *offline algorithm* or *optimal competitive ratio*?

Optimal Offline Algorithm

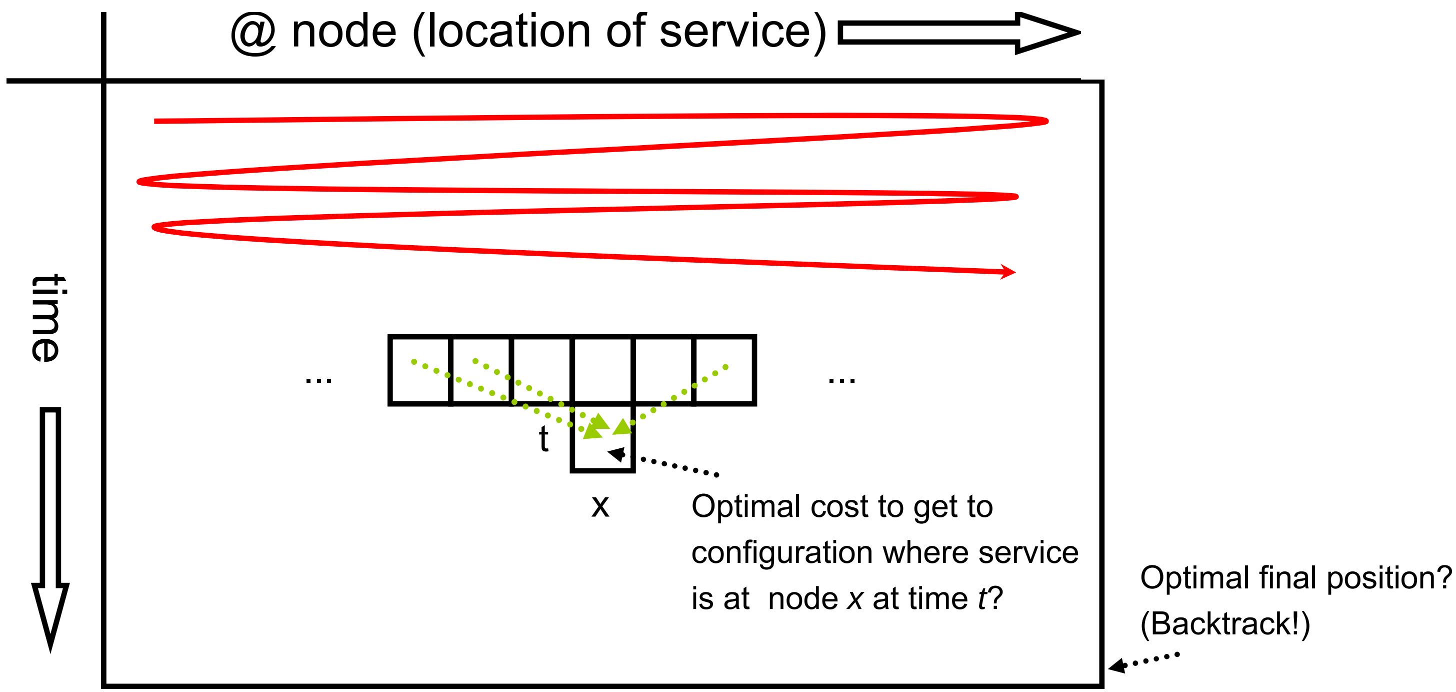
Can be computed using dynamic programming!

Filling out a for optimal server configuration (at node *u* at time *t*):

OPT

opt[u,t] = $\min_{v \in V}$ {opt[t-1][v] + MIG(v,u) + ACC(u,t)}

Visualization:



Online Algorithm: Center to Gravity Approach

Idea: Migrate to center of gravity when access cost at current node is as high as migration cost!

Time between two migrations: *phase*

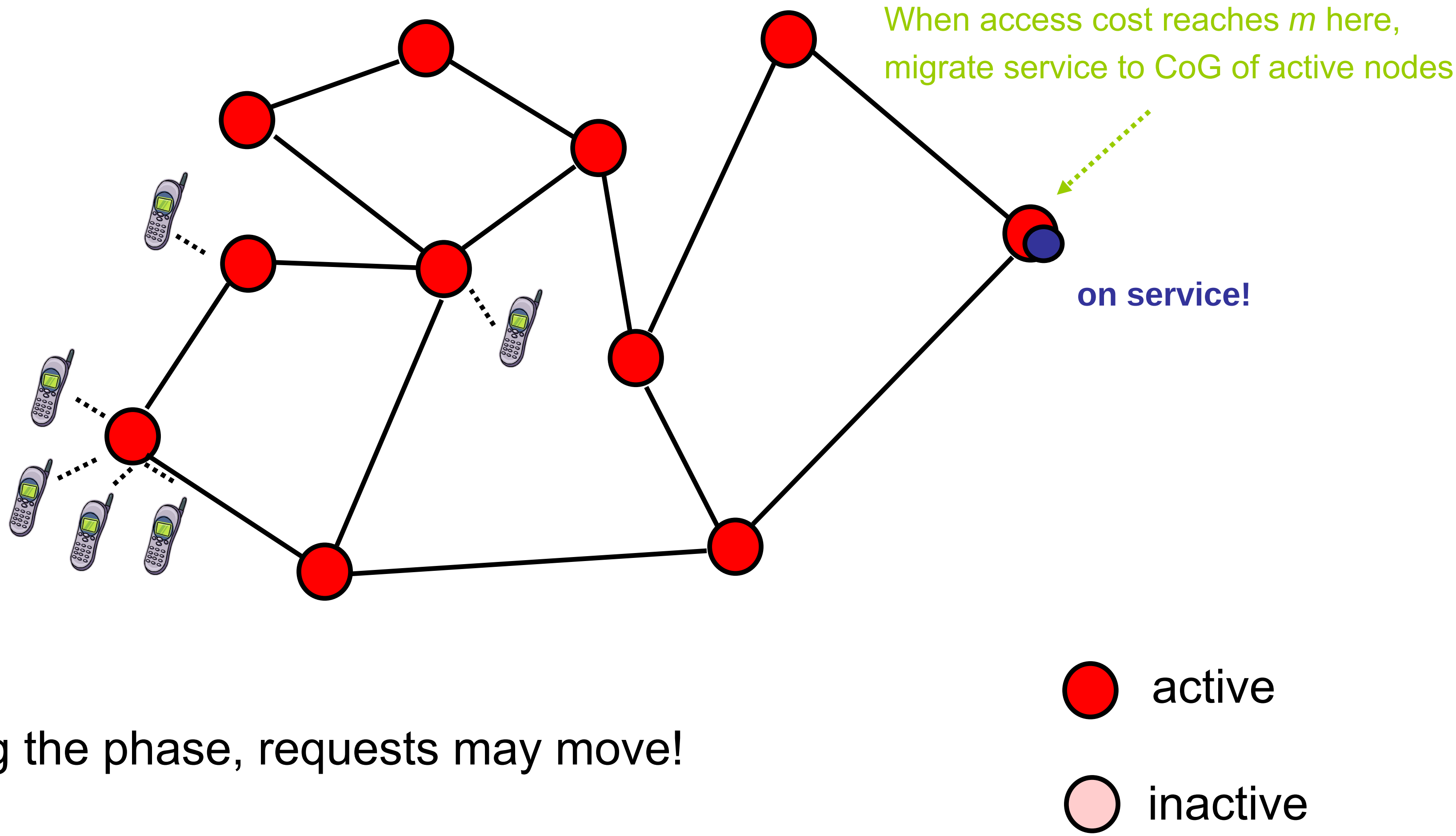
Multiple phases constitute an *epoch*

ALG

For each node *v*, use COUNT(v) to count access cost if service was at *v* during entire ***epoch***. Call nodes v with COUNT(v) < *m*/40 ***active***. If service is at node *w*, a ***phase*** ends when COUNT(w)$\geq$m: the service is migrated to the ***center of gravity*** of the remaining active nodes („center node“ wrt latency or hop distance). If no such node is left, the epoch ends.

Online Algorithm: Visualization

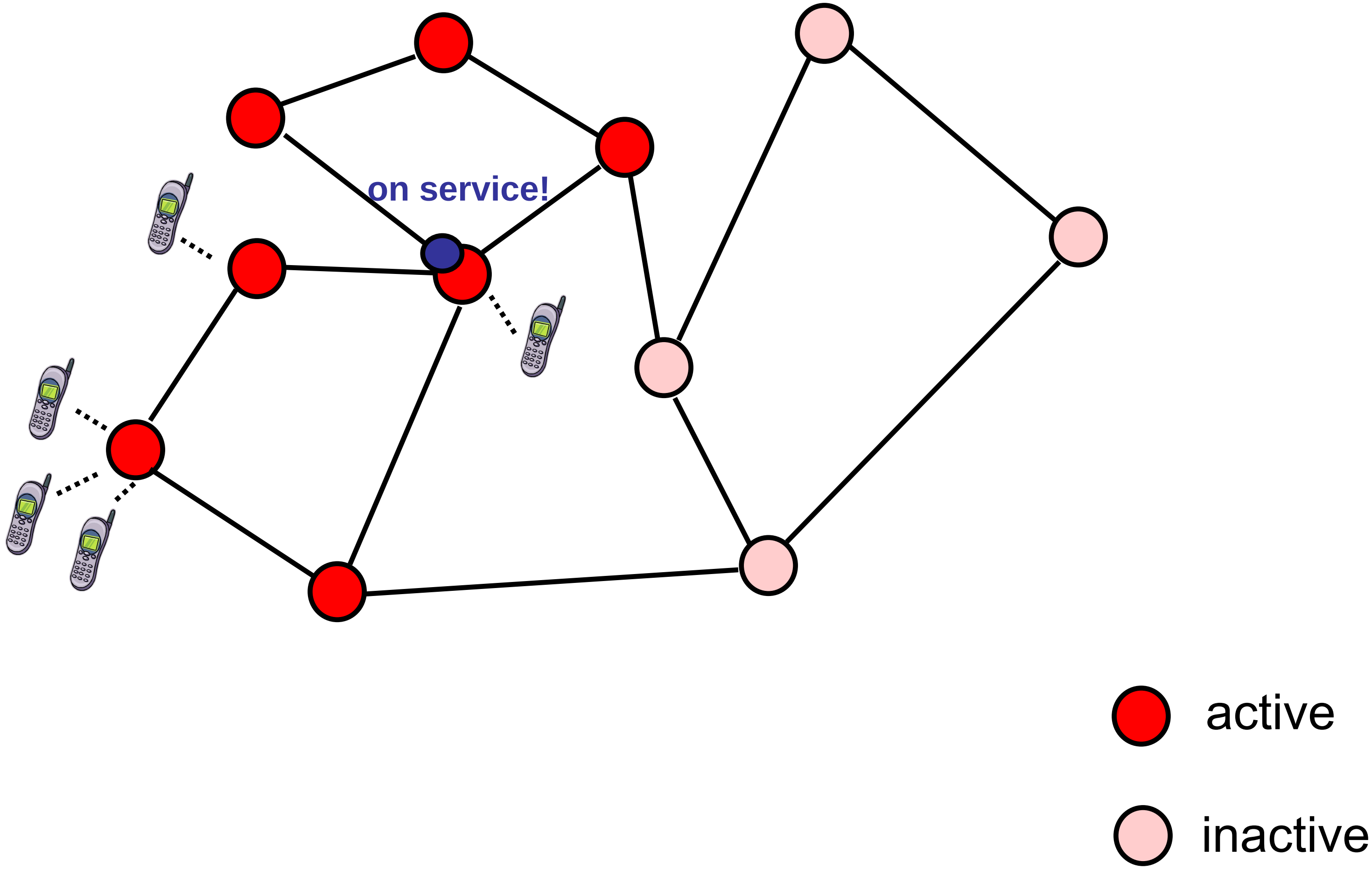
Before phase 1:



During the phase, requests may move!

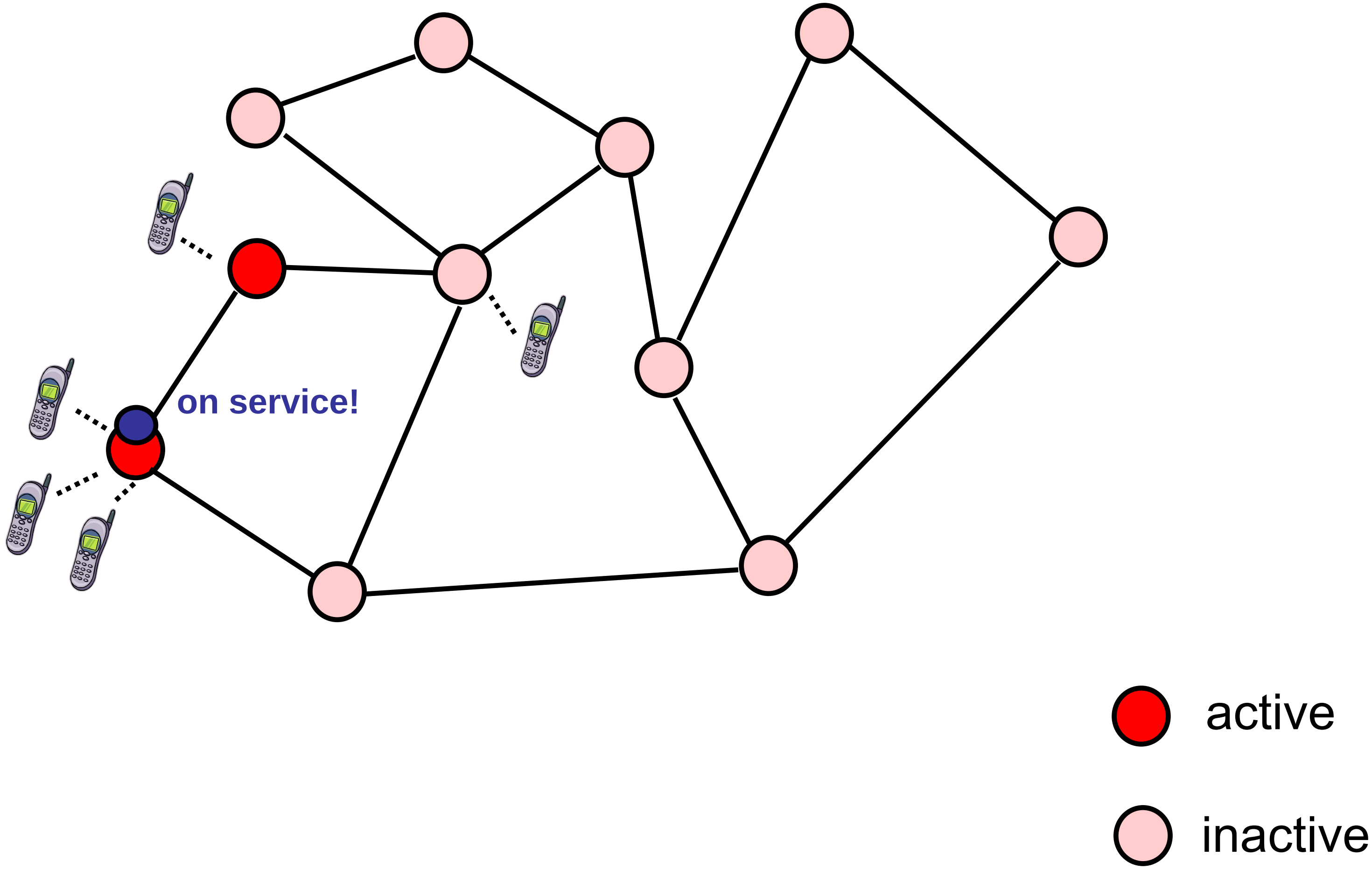
Online Algorithm: Visualization

Before phase 2:



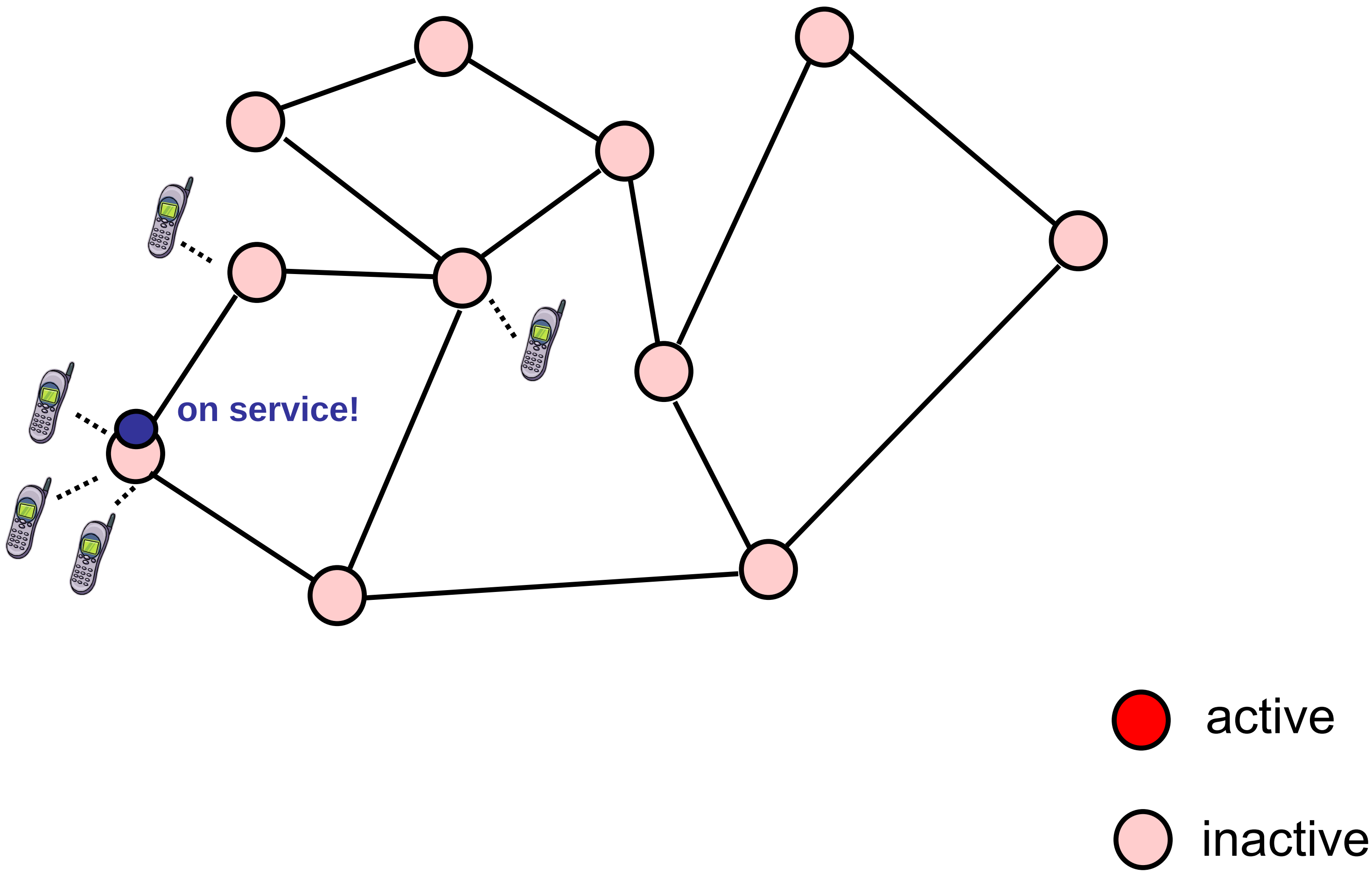
Online Algorithm: Visualization

Before phase 3:



Online Algorithm: Visualization

Epoch ends!



Online Algorithm: Analysis

Competitive analysis?

$$\mathbf{r = ALG / OPT \leq ?}$$

Lower bound cost of OPT:

In an epoch, each node has at least access cost *m*, or there was a migration of cost *m*.

Upper bound cost of ALG:

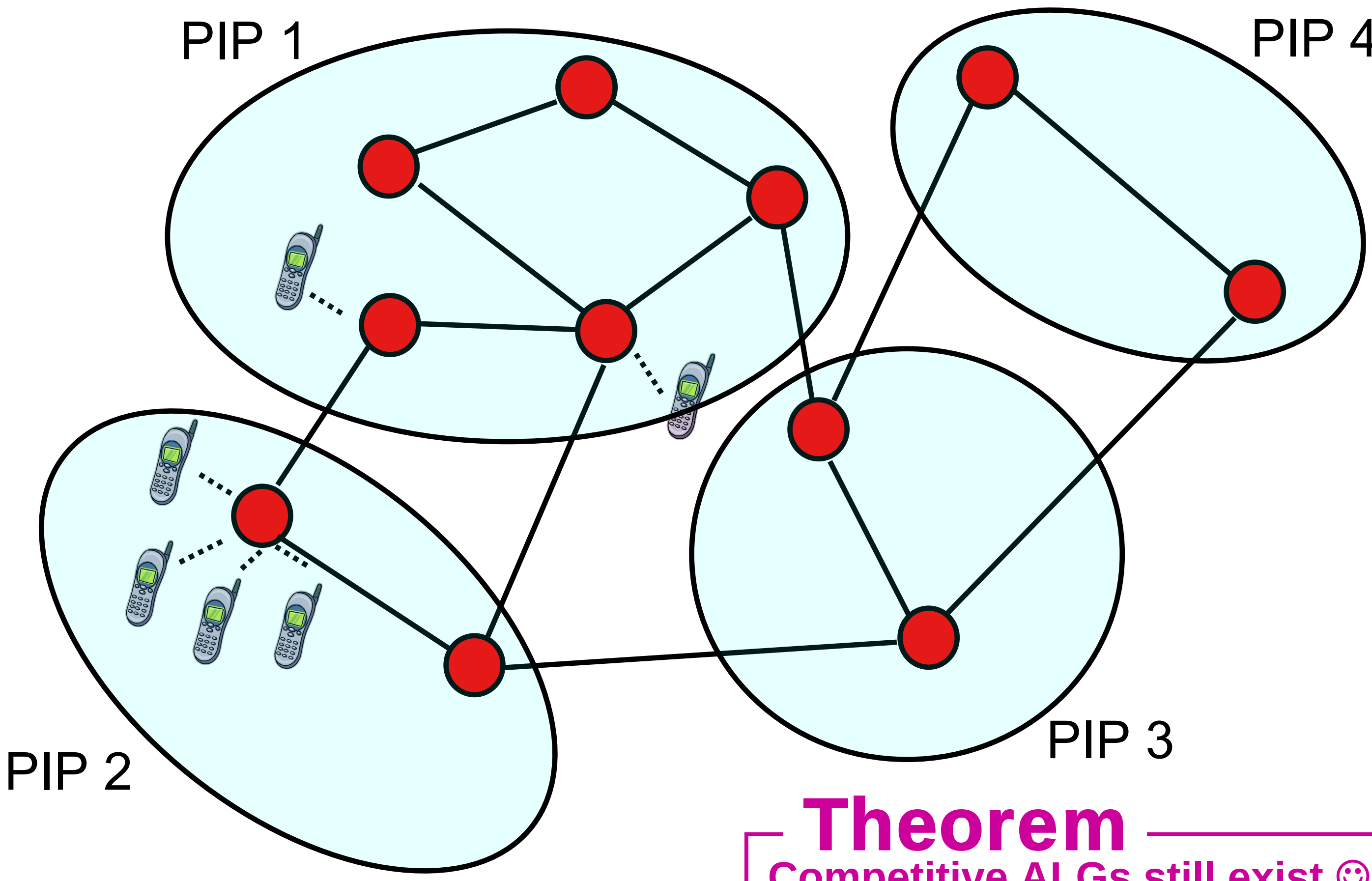
We can show that each phase has cost at most *2m* (access plus migration), and there are at most *log(m)* many phases per epoch!

Theorem

ALG is log(m) competitive!

Reality is more complex...: Multiple PIPs

Migration across provider boundary costs transit costs, detailed topology not known, etc.



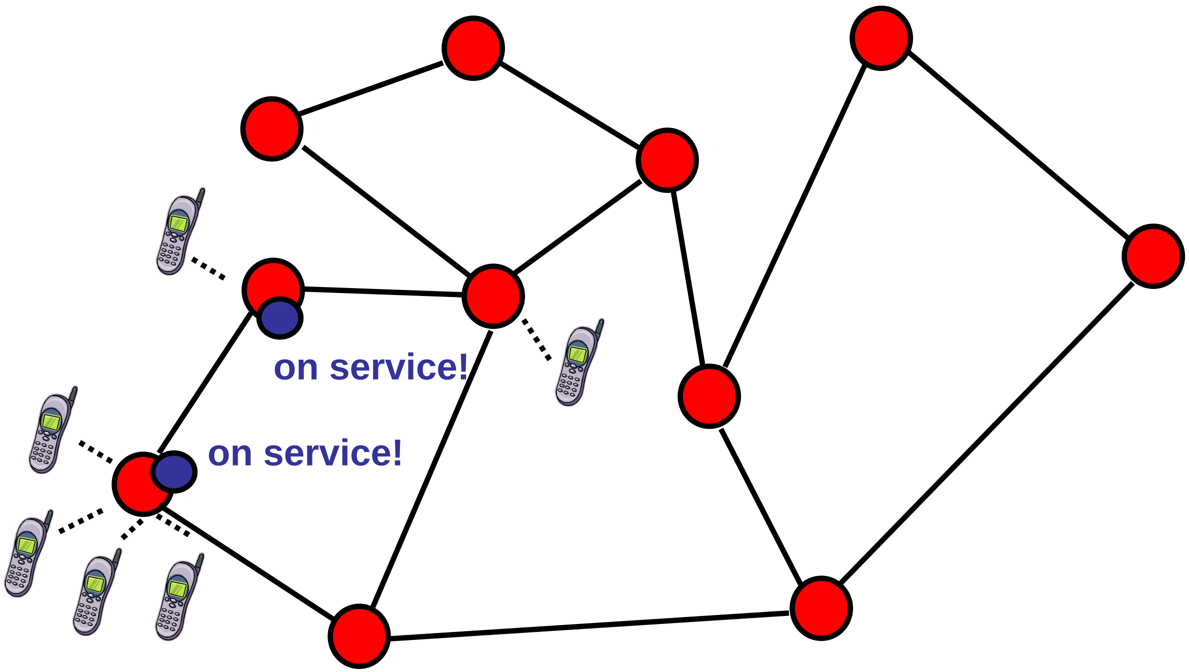
Theorem

Competitive ALGs still exist ☺!

Idea: Two layers of 1 PIP algo...

Reality is more complex...: Multiple Servers

Multiple servers allocated dynamically depending on load, etc.



Theorem

Competitive ALGs still exist ☺!

Idea: via configurations...

Network virtualization architecture and prototype:

Prof. Anja Feldmann, Gregor Schaffrath, Stefan Schmid (T-Labs/TU Berlin)

Service migration

Dushyant Arora (BITS) and Marcin Bienkowski (Uni Wroclaw)

VNet embeddings

Guy Even and
Moti Medina (Tel Aviv Uni),
Carlo Fürst (TUB)

Economics

Arne Ludwig (TUB)

TUB students on bord...

Ernesto Abarca,
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Johannes Grassler,
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etc.

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Thank you for your interest!